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TECHNICAL REPORT NO. 66-109

OPERATION OF TFSO

Quarterly Report No. 6, Project VT/5055

1 August 1966 through 31 October 1966

TELEDYNE INDUSTRIES
GEOTECH DIVISION
GARLAND TEXAS

TECHNICAL REPORT NO. 66-109

OPERATION OF TFSO

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1 August 1966 through 31 October 1966

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

TELEDYNE INDUSTRIES
GEOTECH DIVISION
3401 Shiloh Road
Garland, Texas

1 December 1966

IDENTIFICATION

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Program Manager:	B. B. Leichliter, BR8-8102

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ABSTRACT

This is a report of the work accomplished on Project VT/5055 from 1 August through 31 October 1966. Project VT/5055 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO. Research and development tasks performed by the Garland, Texas, staff using TFSO data are included.

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OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

1. INTRODUCTION

1.1 AUTHORITY

The research described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract AF 33(657)-14444. The contract was dated 12 April 1965; the statement of work for Project VT/5055 is included as the appendix to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was originally constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and seismometric recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by the Earth Sciences Division of Teledyne Industries under Contract AF 33(657)-7747. In March 1964, the Long-Range Seismic Measurements (LRSM) Program provided eight mobile seismic recording vans to extend the existing instrument arrays at TFSO. On 1 May 1965, Geotech assumed the responsibility for operating TFSO. The LRSM mobile vans were phased out of the TFSO operation on 3 October 1965.

The location of TFSO is shown in figure 1.

2. OPERATION OF TFSO

2.1 GENERAL

Data are recorded at TFSO on a 24-hour-a-day basis. The observatory is manned continuously. Five days a week, a full complement of personnel is on duty 8 hours a day; at other times, a reduced operating crew is on duty.

Figure 1. Location of TFSC

G 650

Figure 1. Location of TFSC

G 650

2.2 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are made routinely, and parameters are checked and reset to maintain the specified tolerances.

Normalized response characteristics of TFSO standard seismographs are shown in figure 2.

In addition to these standard seismographs, ΣT has two separate filtered outputs. A UED filter (ΣTF) with a high-cut at 1.75 cps at 24 dB per octave, and low-cut at 0.7 cps at 24 dB per octave is recorded on 16-millimeter film Data Trunks 1 and 7, and on magnetic tape Data Trunks 2 and 5.

A Krohn-Hite filter (ΣTFK), high cut at 3.0 cps at 24 dB per octave, and low-cut at 1.0 cps at 24 dB per octave, is recorded on film Data Trunk 1.

2.3 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO is assigned a data group number. When a data format is changed, a new data group number is assigned to the format. Data format change notices with the changes in channel assignments and data group numbers made during this reporting period were submitted to the Project Officer and to frequent users of TFSO data.

2.4 COMPLETION AND SHIPMENT OF DATA

The magnetic-tape seismograms are shipped from TFSO each week. Three of the magnetic-tape units record data for the AFTAC VELA Seismological Center (VSC), and three are for use by universities. When data from all three magnetic-tape units are not required by the universities, the observatory notifies VSC.

Film records from 10 Develocorders are routinely shipped to data users. The film and magnetic-tape operation logs and calibration logs are copied and shipped with the seismograms to each user. Sets of selected Develocorder prints are sent to Geotech regularly and to other data users on special request. The shipments of 16-millimeter film seismograms routinely sent to the Seismic Data Laboratory (SDL) repository are complete through 31 August.

Table 1. Operating parameters and tolerances of seismographs at TFSO

Seismograph				Operating parameters and tolerances				Filter settings		
System	Comp	Type	Model	Ts	λs	Tg	λg	δ^2	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP	Z	Johnson-Matheson	6480	1.25±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.0117	0.1 - 100	12
SP	H	Johnson-Matheson	7515	1.25±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.0117	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.0104	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.0104	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%	0.0245		
SP	H	UA Benioff	1101	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%	0.0245		
IB	Z	Melton	10012	2.25±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.0006	0.05 - 100	18
IB	H	Lehner-Griffin	SH-216	2.25±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.0004	0.05 - 100	18
BB	Z	Press-Ewing	SV-232	12.0 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.00027	0.05 - 100	18
BB	H	Press-Ewing	SH-242	12.0 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.00027	0.05 - 100	18
LP	Z	Geotech	7505A	20.0 ±5%	0.74 ±10%	110.0 ±10%	0.83 ±10%	0.66	25 - 1000	12
									20 - 200[aa]	12
LP	H	Geotech	8700C	20.0 ±5%	0.74 ±10%	110.0 ±10%	0.83 ±10%	0.66	25 - 1000	12
									20 - 200[aa]	12

KEY

SP Short period
IB Intermediate band
BB Broad band
LP Long period
UA Unamplified (i.e., earth powered)

Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
λs Seismometer damping constant
λg Galvanometer damping constant

[aa] With a 6-second notch filter

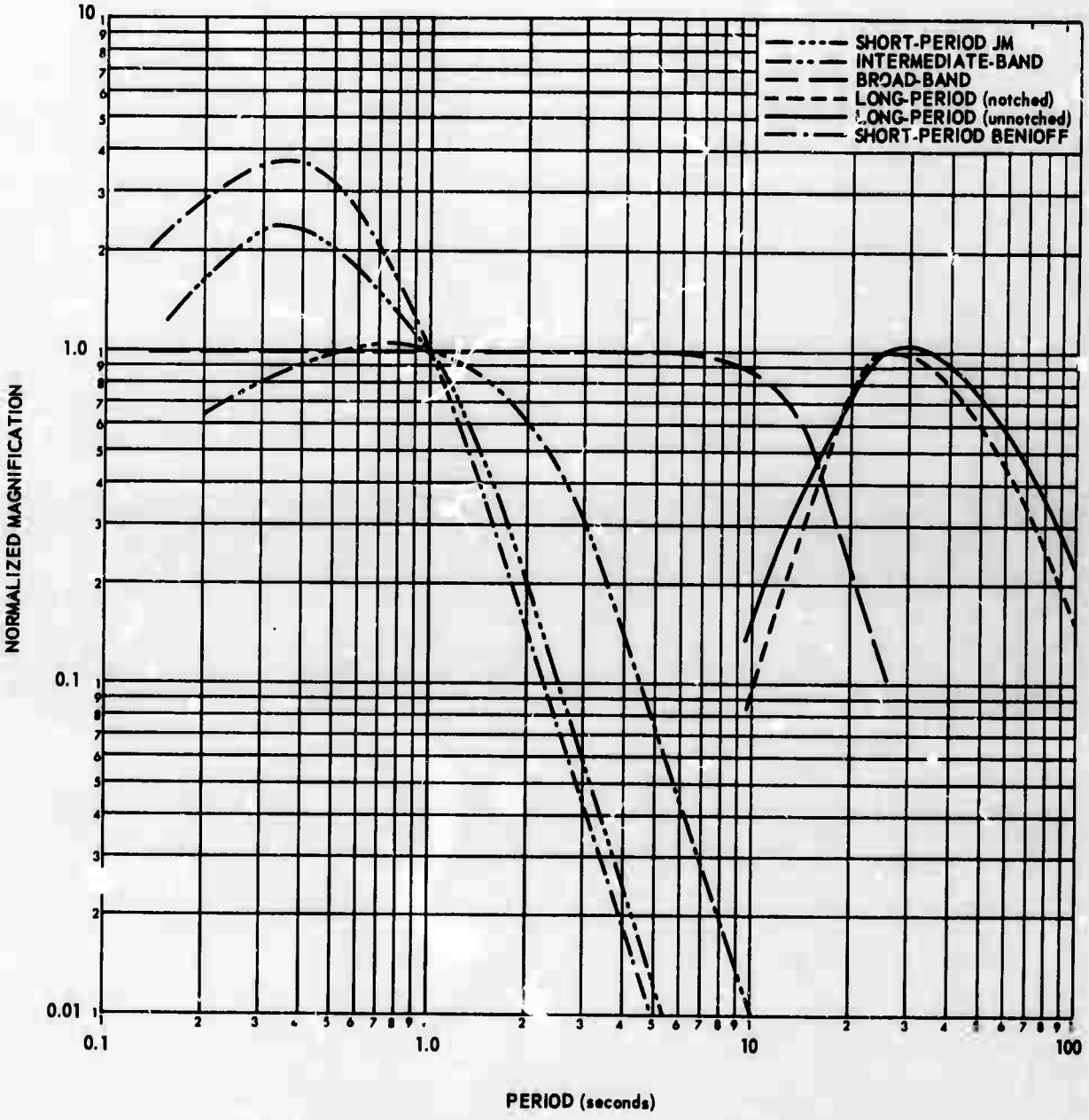

Figure 2. Normalized response characteristics of standard seismographs at TFSO

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2.5 QUALITY CONTROL

2.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly selected runs of 16-millimeter film from Data Trunks 1, 2, and 8, and the accompanying logs are made in Garland. Items that are routinely checked by the quality control analyst include:

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

c. Film;

1. Quality of the overall appearance of the record (for example, trace spacing and trace intensity);

2. Quality of film processing;

d. Analysis - completeness, legibility, and accuracy of the analysis sheets.

Results of these evaluations are sent to the observatory for their review and comment.

2.5.2 Quality Control of Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms were made in Garland and at TFSO to assure that recordings met specified standards. The following are among the items that were checked by the quality control group.

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape where applicable;

d. Seismograph polarity;

e. Level of calibration signals;

f. Relative phase shift between array seismographs;

g. Level of the microseismic background noise;

h. Level of the system noise;

i. PTA dc balance;

j. Oscillator alignment;

k. Quality of the recorded WWV signal where applicable;

l. Time pulse carrier;

m. Binary coded digital time marks.

2.6 VANDALISM

Vandals shot into, and damaged, two sections of spiral-four cable on 21 August 1966. At this time, two junction boxes were shot and a cable road crossing sign was destroyed. This type of vandalism has been rare at TFSO in the past. The damage was found at points in the array closest to a small area being developed for summer homes.

2.7 SECURITY INSPECTION

Mr. Ray Posage, Industrial Security Specialist from Phoenix, Arizona, made a routine security inspection of the observatory on 26 August. All items were found to be in order. The new Industrial Security Manual was reviewed with the station security supervisor.

2.8 SHIPMENT OF CABLE TO USC&GS

At the request of the Project Officer, 269 reels of spiral-four cable were shipped to the U. S. Geological Survey (USGS) at Menlo Park, California. This cable was all considered to be scrap and unusable in the observatory data circuits.

2.9 STATION EQUIPMENT INVENTORY

The annual station equipment inventory was taken during August. A copy of the inventory list was forwarded to the Project Officer.

2.10 CONTRACT EXTENSION

A 2-month, time only contract extension requested on 4 August was approved. The period of operation of TFSO under the present contract has been extended

through 31 December 1966, and the final report is due 60 days following the end of the operating period.

2.11 CHANGES IN OPERATING MAGNIFICATIONS

The operating magnifications of all long-period seismographs were increased during the reporting period. The notched systems are now operated at magnifications of about 60K at 0.04 cps, and the unnotched systems at about 30K.

Because of a seasonal increase in the level of the 5- to 8-second microseisms the operating magnifications of the broad-band systems were attenuated 6 dB.

2.12 CABLE REPLACEMENT SURVEY

The Project Officer requested a summary of spiral-four cable damaged and replaced at TFSO since 1 May 1965. A letter outlining cable replacement was sent on 20 October. Approximately 35 reels have been replaced in the last 18 months. This is a 1.7 percent replacement of all cable lines.

2.13 SPECIAL TEST OF ZHF5

The ZHF5 system was reassembled and a special test recording was made on magnetic-tape on 14 October and sent to the Project Officer at his request.

3. MAINTENANCE OF TFSO EQUIPMENT

3.1 STORM DAMAGE

Many lightning and rain storms occurred during this reporting period. Among the system components damaged by electrical storms were: 6 PTA galvanometers, 3 seismometer data coils, 2 sets of protection diodes, and damaged or increased leakage to ground in several data lines. Figure 3 shows outage due to storms that occurred in 1964, when fuses and carbon blocks were used for lightning protection and in 1966 when AEI gas-triode protectors were used.

3.2 HYPERION TIMING SYSTEM

The Hyperion timing system became temporarily inoperative on 19 August. The cause of the failure was traced to capacitors which were damaged by

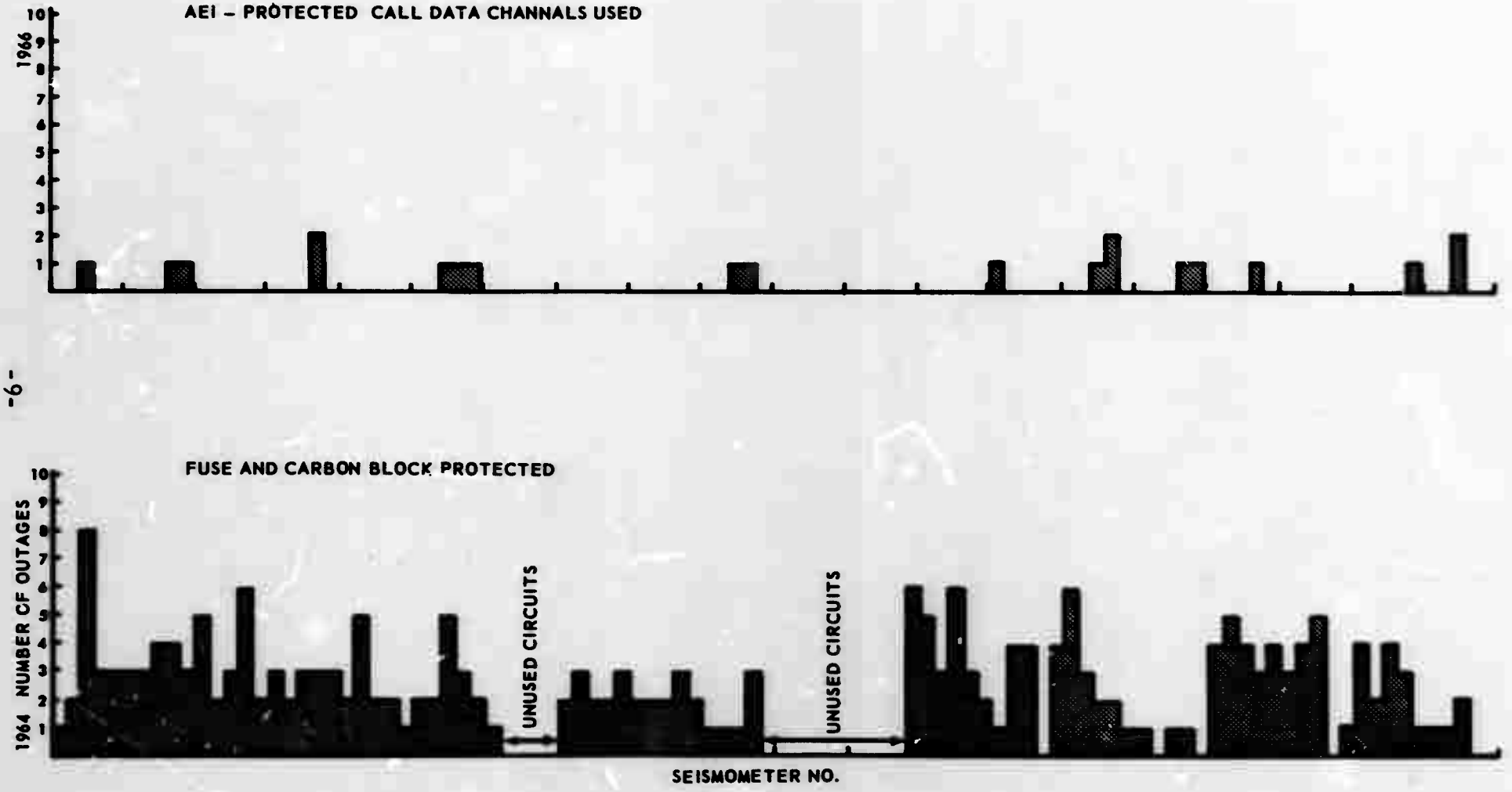

Figure 3. Comparison of number of storm-caused outages at TFSO in 1964 (seismometers protected by fuses and carbon blocks), and 1966 (seismometers protected by AEI lightning protectors

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overheating of the oven. The oven is heated by 2 sets of heating elements, 1 which operates continuously and 1 which operates under the control of a thermostat. Failure of the thermostat to open the oven circuit resulted in overheating of the oven. The thermostatically controlled heaters were temporarily bypassed and the timing system was returned to operation.

On 14 September, the Hyperion timer stopped operating. Adjustments were made to the Schmidt trigger (ST 1-A) and the timer was restarted. No faulty components were found. The thermostat in the oven assembly was replaced at this time.

3.3 SHALLOW-HOLE SEISMOMETERS Z 102SG and Z103SH

The shallow-hole seismometers Z 102SG and Z 103SH were removed from the hole for repairs of the data coil leads which had been damaged by lightning.

During this operation, the mass-positioning controls in the Geotech Model 20171 seismometer were bent. Replacement parts were installed, and both units were back in operation by 12 August.

3.4 ROUTINE TESTS AND CHECKS

3.4.1 PTA Linearity

Quarterly PTA linearity checks were made during August. The free-period and damping of the PTA galvanometers in all seismographs used in the 31-element array were checked during this reporting period.

3.4.2 Annual Seismometer Motor Constant Check

Annual seismometer calibrator motor constant (G) checks were started during August and completed in October. Table 2 shows the results of the G determinations. Note that an unusually large number of horizontal seismograph calibrators required adjustment. The reasons for this are unknown. G determinations for short-period horizontal seismographs are inherently more susceptible to measurement errors under field operating conditions than are G determinations for vertical seismographs because of the precision required in installation of the weight-lift jig on the seismometer. The large number of horizontal seismograph G's that required adjustment can be, in part, attributed to these difficulties in measuring accurately; however, it is probable that other factors, causing actual G variation, are also involved.

Table 2. TFSO annual motor constant check

System	Previous "G"	1st check	Adjusted	Used for calibration
Z1	0.296	0.2975		0.296
Z2	0.2935	0.310	0.216	0.296
Z3	0.305	0.295		0.296
Z4	0.299	0.295		0.296
Z5	0.3025	0.300		0.296
Z6	0.298	0.300		0.296
Z7	0.297	0.303		0.296
Z8	0.2965	0.301		0.296
Z9	0.298	0.2875		0.296
Z10	0.2945	0.2935		0.296
Z11	0.2975	0.2861	0.296	0.296
Z12	0.3005	0.3041		0.296
Z13	0.2955	0.289		0.296
Z14	0.3075	0.293		0.296
Z15	0.3035	0.3055	0.2925	0.296
Z16	0.302	0.321	0.2915	0.296
Z17	0.303	0.2885		0.296
Z18	0.296	0.296		0.296
Z19	0.297	0.300		0.296
Z20	0.2945	0.3175	0.2955	0.296
Z21	0.295	0.284	0.2955	0.296
Z22	0.297	0.294		0.296
Z23	0.294	0.2915		0.296
Z24	0.295	0.296		0.296
Z25	0.294	0.2995		0.296
Z26	0.299	0.304		0.296
Z27	0.3015	0.302		0.296
Z28	0.2925	0.303		0.296
Z29	0.291	0.2945		0.296
Z30	0.2765	0.2965		0.296
Z31	0.292	0.285	0.2995	0.296
E36	0.2945	0.2995		0.296
N37	0.303	0.3125	0.2965	0.296
Z38BB	0.185	0.186		0.188
E39BB	0.1865	0.186		0.188
N40BB	0.187	0.1725	0.190	0.188
Z41IB	0.02075	0.0212		0.0206
E42IB	0.04675	0.0491	0.0474	0.0474
N43IB	0.0476	0.0482		0.0474
Z44LP	0.03175	0.0303		0.032 [a]
E45LP	0.0311	0.0301		0.032 [a]
N46LP	0.0322	0.0250		0.032 [a]
Z47BF	2.38	2.385		2.43
E48BF	2.28	2.31		2.26
N49BF	2.27	2.305		2.26
1A	2.12	2.10		2.12
1B	2.21	2.20		2.20
1C	2.18	2.085	2.18	2.20

Table 2. (Continued)

System	Previous "G"	1st check	Adjusted	Used for calibration
Z60	0.300	0.298		0.296
Z61	0.304	0.296		0.296
Z62	0.304	0.290		0.296
Z63	0.302	0.295		0.296
Z64	0.291	0.298		0.296
Z65	0.2975	0.296		0.296
Z66	0.2965	0.2875		0.296
Z67	0.3025	0.3025	0.2965	0.296
Z68	0.297	0.295		0.296
Z69	0.3015	0.304		0.296
Z70	0.295	0.2955		0.296
Z71	0.300	0.300		0.296
Z72	0.296	0.295		0.296
Z73	0.297	0.292		0.296
Z74	0.289	0.296		0.296
T75	0.300	0.275	0.293	0.296
R76	0.2925	0.280	0.2945	0.296
T77	0.3905	0.275	0.293	0.296
R78	0.2945	0.251	0.295	0.296
T79	0.3015	0.284	0.294	0.296
R80	0.2915	0.2825	0.294	0.296
T81	0.2965	0.277	0.298	0.296
R82	0.2955	0.277	0.292	0.296
T83	0.2945	0.272	0.2925	0.296
R84	0.292	0.2705	0.292	0.296
T85	0.2955	0.293		0.296
R86	0.2975	0.290		0.296
T87	0.2945	0.288		0.296
R88	0.2975	0.294		0.296
R89	0.2985	0.281	0.296	0.296
T90	0.299	0.2765	0.296	0.296
R91	0.296	0.308	0.2935	0.296
T92	0.2945	0.288		0.296
R93	0.2945	0.2775	0.293	0.296
T94	0.295	0.296		0.296
R95	0.295	0.2285	0.299	0.296
T96	0.293	0.2725	0.2965	0.296
R97	0.292	0.299		0.296
T98	0.298	0.2755	0.296	0.296
Z99	0.295	0.2985		0.296
Z100	0.298	0.2965		0.296

[a]0.0300 used for daily calibrations after 27 October 1966

3.4.3 Phase-Shift Checks

Routine phase-shift checks were performed on all Johnson-Matheson seismometers during this reporting period. Only two seismometers showed excessive phase-shift, and in both cases the cause was traced to foreign matter in the air gap.

3.5 MAINTAIN TFSO FACILITIES

3.5.1 Water-Chiller Units

During this reporting period, a careful watch has been kept on the water-chiller units to determine if the scale buildup is being controlled. No additional problems have been observed.

3.5.2 Interior of Central Recording Building

Painting of the interior of the central recording building has continued. Approximately 40 percent is completed.

4. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

4.1 MODIFICATIONS TO TFSO INSTRUMENTATION

4.1.1 Telemetry Site Restorations

Restoration of the TFSO extended array van locations was completed during August. The Seligman, Arizona site, from which about 38 reels of spiral-four cable were recovered, was the last site to be restored. Also, work on the Myrtle Point relay site was completed, and an inspection of this site was made by representatives of the U. S. Forest Service.

4.1.2 Power Switching Unit Modification

Circuits of the power switching unit of the Model 22183 1 kW inverter were modified to stabilize the square-wave output. Both the primary and secondary drive now provide suitable inputs. A major problem still exists in the inverter, however. The inverter shuts down when certain of the loads are switched. A similar unit belonging to UBSO has been returned to our Garland laboratory so that we can modify the inverter to solve this problem. After the UBSO inverter has been successfully modified, the necessary changes will be made in the TFSO unit. The power amplifier will replace ten 100-watt Rogan

amplifiers presently supplying frequency regulated power to the Develocorder magnetic-tape recorders and Helicorders.

4.2 TESTING OF TFSO INSTRUMENTATION

4.2.1 Defoliation Around Long-Period Vault

All vegetation in the area surrounding the long-period vault was removed earl in August, and the ground was sprayed with white-wash to provide a reflecting surface. This was done to determine whether the effects of diurnal temperature variations on the seismometers could be significantly reduced, thereby affording improved long-period seismograms. Initial results appeared encouraging; however, no long-term data were obtained which indicated that significant improvement was achieved. Rain washed away 50 percent of the solution within a week. The spraying operation was repeated, but rain again washed away a major part of the solution. It is our opinion that no significant improvement of the long-period environment was achieved.

5. ANALYZE DATA

5.1 REPORT EVENTS TO U. S. COAST AND GEODETIC SURVEY

Analysts report the time of arrival, period, and ground displacement amplitude of events recorded at TFSO to the Director of the United States Coast and Geodetic Survey (USC&GS) in Washington, D. C., daily. The number of events reported by TFSO during each month of this reporting period is shown in table 3, by type. The total number of events recorded by the observatory, the number of events located by USC&GS and reported in the Preliminary Determination of Epicenter cards, and the percentage of these hypocenters for which TFSO data were used for the period March through July are shown in table 4. Lists of more recent epicenters have not yet been completed by USC&GS.

5.2 DAILY ANALYSIS FOR MULTISTATION EARTHQUAKE BULLETIN

Data from TFSO are combined with data from CPSO, BMSO, UBSO, and WMSO and published in a monthly multistation earthquake bulletin. The bulletins for March, April, and May 1966 were published during this reporting period.

Raw data for June and July were transcribed onto digital magnetic tape and sent to SDL for processing. The Automated Bulletin Process (ABP) output

Table 3. Number of earthquakes reported to USC&GS by TFSO during August, September, and October 1966

August 1966					September 1966				
L	N	R	T	Total	L	N	R	T	Total
11	923	23	1458	2415	36	609	35	1243	1923

October 1966				
L	N	R	T	Total
10	325	20	1371	1726

L = Local
N = Near regional
R = Regional
T = Teleseisms

of a portion of the June data was received from SDL; however, the entire bulletin was not processed due to recurring diagnostic error printouts during processing of the first portion of the data. The cause of the diagnostics was traced to errors in the TFSO input data that were not detected by our raw-data check program. The check program was revised to flag errors of these types, and the June and July raw-data were resubmitted for the ABP.

Raw data for August and September have been keypunched, transcribed onto tape, and will be sent to SDL for processing. Keypunching of October raw data is about 50 percent complete.

5.3 CONTINUE NOISE SURVEY

Measurements of ambient noise in the 0.4- to 1.4-second period range are made daily at TFSO. Data are processed in Garland, and monthly cumulative probability curves of trace amplitude and ground displacement as recorded on the Z1, ΣT, and ΣTF seismograms are published. Curves for months of June, July, and August 1966 were sent to the Project Officer during this reporting period.

Table 4. Number of earthquakes reported by TFSO and number and percentage of hypocenters reported in the USC&GS "Earthquake Data Report" for which TFSO data were used

	Events reported by TFSO	Hypocenters reported by USC&GS	Percent of USC&GS events utilizing TFSO data
March 1966	1274	432	71.8
April 1966	1286	401	78.3
May 1966	1369	442	76.2
June 1966	1403	446	73.5
July 1966	1287	338	82.5

6. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

6.1 ASTRODATA DATA ACQUISITION SYSTEM (ASDAS)

A failure in the core memory circuits of the ASDAS occurred in September. The failure was similar to the last breakdown and the faulty components were found and repaired in less than 4 hours. An intermittent failure was discovered on 15 October and was found to be a faulty transistor in the memory output circuits which was repaired on 24 October. A total of 22 digital tapes were recorded during this reporting period.

6.2 RECORDINGS FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Weekly shipments of 16-millimeter film, Data Group 7189, were sent to the California Institute of Technology (Cal Tech), except for data requested by VSC which are sent to SDL. A new recording format for the magnetic-tape recorders not presently in use is being planned by VSC.

6.3 TELEMETRY TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Telemetry of seven seismograph channels to Lincoln Labs, Massachusetts Institute of Technology (MIT), continued throughout this reporting period. During periods of seismograph attenuation and special tests, MIT is notified when possible.

6.4 ASTROGEOLOGICAL DEPARTMENT OF USGS

Dr. Harold Kirvoy of the Astrogeological Department of the United States Geological Survey (USGS) in Flagstaff, Arizona, requested the cooperation of TFSO in providing periodic information on events. Dr. Kirvoy has been placed on the distribution list of the multistation earthquake bulletin, and also receives a copy of the TFSO daily message to USC&GS.

6.5 SPECIAL REPORTS TO THE USC&GS

In addition to the routine daily messages, TFSO cooperates with the USC&GS in providing information on specified events as requested. One example of this is the reporting of aftershocks of the Utah event on 16 August. Approximately 750 aftershocks of this event were reported by TFSO from 16 through 25 August.

6.6 VISITORS

Mr. B. B. Leichliter, Teledyne Program Manager, visited TFSO from 25 through 27 September to review the operation of the observatory and to be present during the visit to TFSO scheduled by Senator Barry Goldwater. However, the Senator was forced to cancel his visit because of last minute changes in his schedule.

Mr. C. P. Fink and Mr. H. E. Klindert from the Phoenix office of the Los Angeles Defense Contract Administration Services Region (DCASR) visited TFSO on 12 October. The purpose of the visit was in compliance with the visit regulations of the Small Business Administration.

TFSO opened its facilities to students and professors from Arizona State University during both the summer and fall sessions. A class from the local elementary school has visited the observatory.

7. DEVELOPMENTAL FUNCTION

A letter report outlining an automatic calibration unit for TFSO and requesting authority to develop same was sent to the Project Officer on 7 October. No action has been taken on this matter.

8. RESEARCH PROGRAMS

8.1 SIGNAL CLASSIFICATION STUDY

A classification of earthquake signals based on visual characteristics of longitudinal waves (typically P or PKP) as recorded on the ΣT seismograph is being developed. During this reporting period, approximately 150 earthquakes of magnitude 5.0 or above were selected for initial study. The characteristics of these signals are to be compared and various criteria (for example, initial amplitude and number, amplitude relationship, and decay of energy pulses in the first 20 seconds) are to be evaluated.

8.2 ARRAY RECOMMENDATIONS

On 24 June, the Project Officer requested that we review the available data regarding the noise field in the TFSO area, and that we consider redesign of the TFSO array to provide a more satisfactory array. On 7 September, we submitted our Project Recommendation (P-688) for the redesign of the TFSO array. In P-688, we recommended that a 37-element array of short-period vertical seismometers spaced at intervals of 5 kilometers be installed to replace the existing array.

Also at the request of the Project Officer we have been considering the design of an array of long-period seismographs for TFSO. A meeting with the Project Officer is planned at VSC during the week of 31 October to discuss our recommendations regarding both arrays.

8.3 MODIFIED LONG-PERIOD SEISMOMETER

Tests in the long-period seismometer with the wire flexures (NLPX) were continued throughout this reporting period. This experimental seismometer is oriented north-south, and is located on the pier with the standard long-period seismometers.

At the end of the last reporting period, the NLPX showed system spiking, as shown in figure 4. In an effort to eliminate this spiking, the seismometer was heat-cycled for a period of 36 hours. However, after a period of stabilization, no reduction in either the frequency of occurrence or the amplitude of the spikes was observed. Heat-cycling was again repeated, using more heat (100 watts) and for a longer time period (72 hours). Also, a convection shield was added. After stabilization, the noise in the NLPX system was at a level comparable to that observed on the other horizontal systems as shown in figure 5. The spiking problem has not recurred.

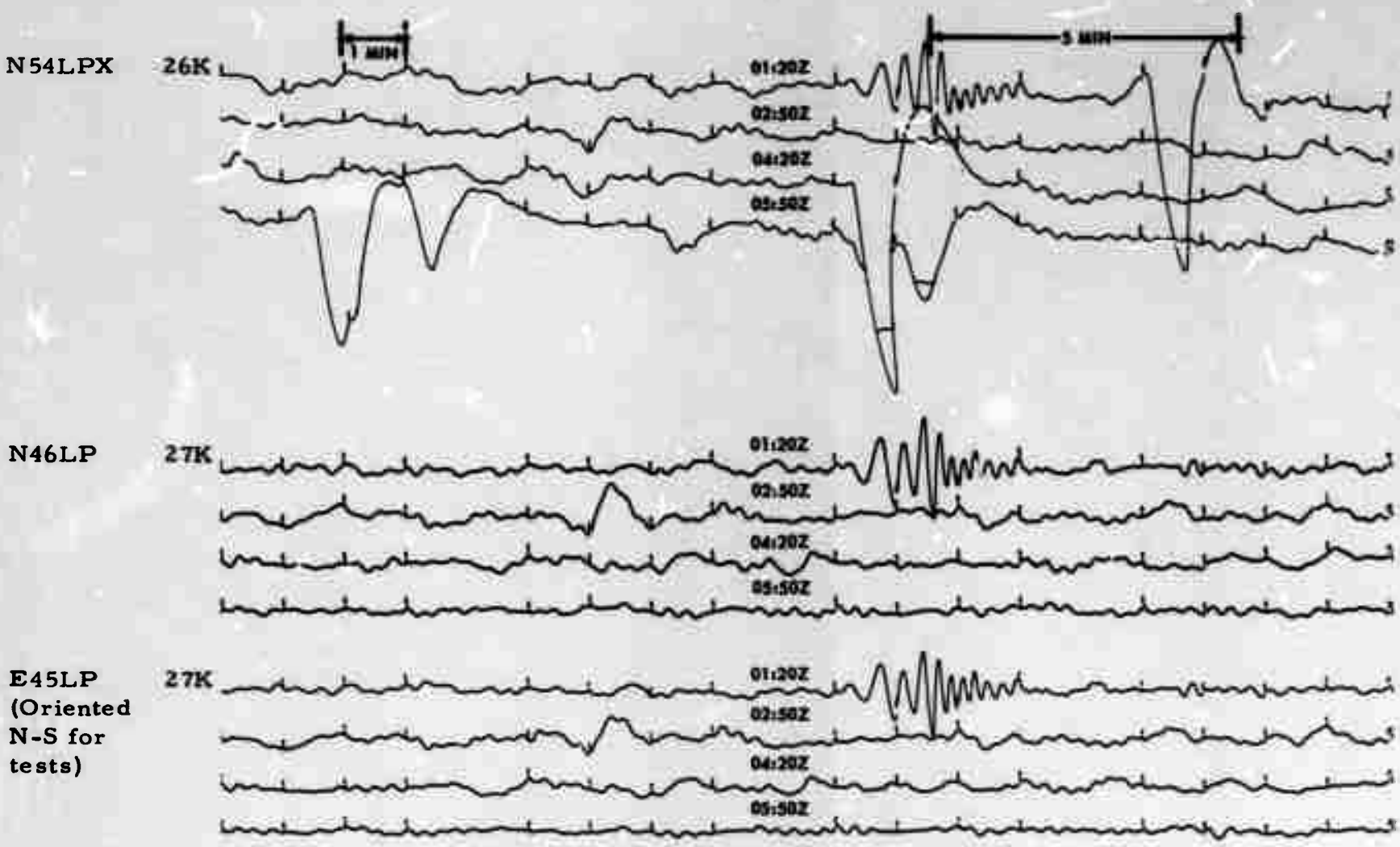
We have not, at this time, determined whether the experimental seismometer is superior to the control seismometers; however, additional tests are in progress from which we hope to resolve this question.

8.4 ARRAY COUPLING STUDY

All signals for the study designed to determine the effect of local geology on signal amplitude across the array have been selected and the data have been punched into IBM cards. A total of 312 signals for each of the 23 vertical short-period seismometers will be evaluated. This study is scheduled for completion by 31 December.

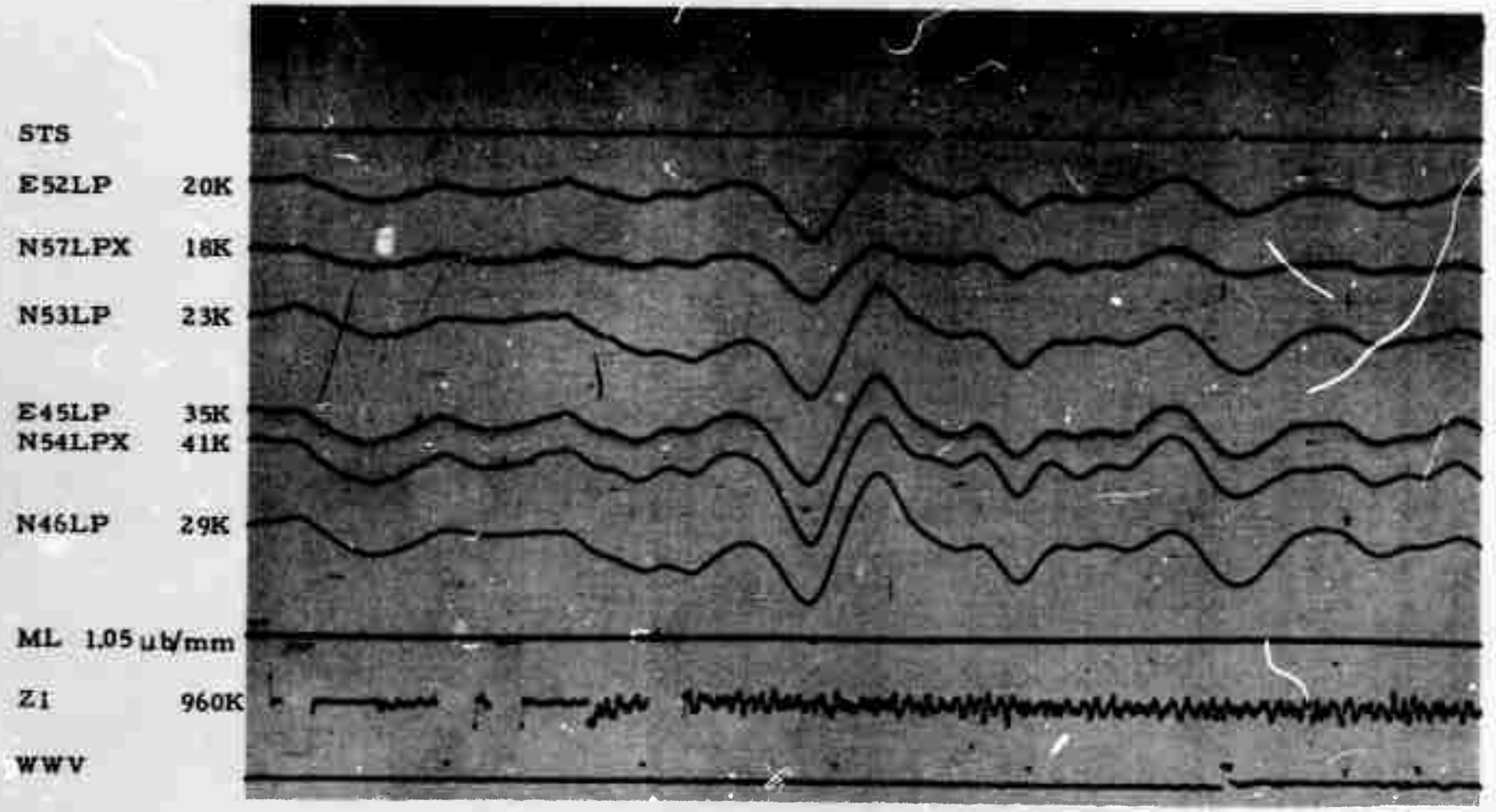
8.5 DESIGN OF AN IMPROVED HIGH-FREQUENCY SEISMOGRAPH

A memorandum describing the requirements of an improved high-frequency seismograph and the various seismograph tests on which these requirements were based, and a request for authority to build a high-frequency seismograph were submitted to the Project Officer in late October. The conclusions of these tests were that eight GS-13V geophones, installed in a pressure case, would provide a satisfactory seismometer for the improved high-frequency seismograph. These geophones are produced by the Engineering Products Company of Tulsa, Oklahoma, and would each be modified to have a 0.453 kg mass and a 2,860 ohm data coil. An Ithaco amplifier was recommended for amplification of the output of this seismometer.



TFSO
Exp LP Helicorder

Figure 4. Long-period seismogram recorded at TFSO showing spikes on N54LPX. Note absence of spikes on control instruments N46LP and E45LP. Signal at 01:21, from unknown epicenter, is comparable on all instruments. (Direct print from Helicorder record)



TFSO
06 Sept 66
Run 249
Exp LP

Figure 5. Long-period seismogram from TFSO, comparing response of experimental seismographs (N57LPX and N54LPX) in signal and noise with standard seismographs. (Control seismographs E52LP and E45LP are oriented N-S for duration of test). Epicenter unknown. (X10 enlargement of 16-millimeter film)

9. REPORTS AND TECHNICAL DOCUMENTS

Several reports and technical documents were prepared under Project VT/5055 during this reporting period. A list of these reports and documents follows.

a. Evalution of the French Seismograph, letter report dated 3 October 1966.

b. Magnitude Studies Conducted Under Projects VT/5054 and VT/5055, Technical Report No. 66-73, by Jack G. Swanson, was mailed to the Project Officer on 31 August.

c. The TFSO Quarterly Report No. 5, Technical Report No. 66-85, was mailed to the Project Officer on 24 August.

d. A letter containing a recommendation to build and install an automatic calibration system for TFSO was submitted to the Project Officer on 7 October 1966.

e. Recommended Orientation for the TFSO Seismograph Array, Project Recommendation P-688, was submitted to the Project Officer on 7 September.

f. Tests of the GS-13V geophone and recommendations for the design of an improved high-frequency seismograph, a letter memorandum, was submitted to the Project Officer on 28 October.

APPENDIX to TECHNICAL REPORT NO. 66-109

STATEMENT OF WORK TO BE DONE

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STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/5055

1. Operation.

a. Operate the Tonto Forest Seismological Observatory (TFSO), normally recording data continuously.

b. Evaluate the seismic data to determine optimum operational characteristics and make changes in the operating parameters as may be required to provide the most effective observatory possible. Addition of new and modification of present on-line instrumentation are within the scope of work. However, such instrument additions and modifications, data evaluation, and major parameter changes are subject to prior technical approval by the AFTAC project officer.

c. Conduct routine daily analysis of seismic data and transmit daily seismic reports to the US Coast and Geodetic Survey, Washington, DC 20230, using the established report format and detailed instructions.

d. Record the results of daily analysis in a format compatible with the automated bulletin program (ABP) used by the Seismic Data Laboratory (SDL), 300 North Washington Street, Alexandria, Virginia 22314, in their preparation of the seismological bulletin of the VELA-UNIFORM seismological observatories. This format may be established by coordination with SDL through the AFTAC project officer. The schedule of routine shipments of this data to SDL will be established by the AFTAC project officer.

e. Conduct quality control (QC), as necessary, to assure the recording of high quality data on both magnetic tape and film. Past experience indicates that QC review of one magnetic tape per magnetic tape recorder per week is satisfactory unless QC tolerances have been exceeded and the necessity of additional QC arises. QC of magnetic tape should include, but need not necessarily be limited to, the following items:

(1) Completeness and accuracy of operation logs.

(2) Accuracy of observatory measurements of system noise and equivalent ground motion.

(3) Quality and completeness of voice comments.

(4) Examination of all calibrations to assure that no clipping occurs.

(5) Determination of relative phase shift among all array seismograph systems.

(6) Measurement of DC unbalance.

Atch 1

(7) Presence and accuracy of tape calibration and alignment.

(8) Check of uncompensated noise on each channel.

(9) Check of uncompensated signal-to-noise of channel 7.

(10) Check of general strength and quality of WWV time.

(11) Check of synchronization of digital time code with WWV.

f. Continue telephone service and VHF telemetry between TFSO and the mobile seismic vans (Project VELA T/4051) located along extensions of the TFSO crossed array.

g. Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after AFTAC approval through the project officer.

h. Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

2. Instrument Evaluation.

a. On approval by the AFTAC project officer, evaluate the performance characteristics of experimental and off-the-shelf equipment offering potential improvement in the performance of observatory seismograph systems. Operation and test of the instrumentation under field conditions should normally be preceded by laboratory test and evaluation.

b. To permit more thorough laboratory evaluations to be conducted at TFSO, improvements to TFSO laboratory capability may be necessary. The contractor should make recommendations for such improvements and, after approval by the AFTAC project officer, implement them.

3. Developmental Function. Operation and evaluation of the observatory's "standard" instrumentation and of "experimental" equipment may disclose the need for supplemental equipment, neither commercially available nor in development under the VELA-UNIFORM program, that could improve the performance and capability of the seismograph systems of TFSO and other VELA-UNIFORM observatories. The contractor should make recommendations on the development of such equipment and, after approval by the AFTAC project officer, proceed with developmental work.

4. Research Programs. On approval by or at the request of the AFTAC project officer, conduct research programs designed to upgrade the TFSO detection capability. Environmental conditions (geological, seismological, and meteorological) affecting the results of these research programs should not be neglected. Research might pursue investigations in, but are not necessarily limited to, the following areas of interest:

a. Microseismic Noise.

(1) Review all available TFSO noise data to guide the direction of additional work. Define and conduct additional surface noise studies as necessary.

(2) Examine noise at shallow depths using existing and additional shallow boreholes. The number, depth, and locations of the additional boreholes must be approved by the AFTAC project officer.

b. Array Detection Capability.

(1) Evaluate combinations of existing vertical and of existing horizontal surface array seismographs to determine the most effective array summations in detecting teleseismic signals. Determine TFSO overall detection capability when using these array summations along with the remaining seismograph systems.

(2) Under Project VELA T/5052, AFTAC has programmed the addition of a multiple array processor to the TFSO instrumentation for the summer of 1965; training in operation, maintenance, and calibration of the processor and in analysis techniques will be provided to appropriate TFSO personnel at the time of installation by the manufacturer, Texas Instruments Incorporated. Evaluate the detection capability of the processor and examine its enhancement, if any, of the overall TFSO capability.

(3) Mobile seismic vans (Project VELA T/4051) are temporarily located along extensions of the TFSO crossed array and the data (3-component short-period) from the vans are recorded at TFSO. Investigate the use of this extended array to improve the TFSO detection capability.

(4) Determine TFSO deficiencies, if any, that degrade the observatory's detection capability. Prepare and submit to the AFTAC project officer recommended improvements designed to eliminate such deficiencies and enhance the detection capability.

c. Visual Data Presentation. Investigate forms of visual data presentation which would improve detection of seismic signals by visual on-line analysis.

Programs implemented should be planned for completion during the contracted period of TFSO operation. Furthermore, prior to commencing any research program, AFTAC approval must be obtained of a comprehensive outline for each research program instituted.